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SIGNIFICANT CHARACTERISTICS OF SOCIAL RESPONSE TO NOISE AND VIBRATION

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16. Abstract

Since 1971 several surveys have been made investigating annoyance resulting from noise and vibration, from various sources. Here several significant characterstics of individual/social attitude are discussed from the common standpoint in these surveys, including methodological aspects. Objectives were to quantify the relation between annoyance response to noise or vibration and properties of the respondent including factors such as noise exposure, etc. Samples collectd by the social surveys and physical measurements were analyzed by multi-dimensional analysis (quantification theory of qualitative data proposed by Dr. Hayashi).

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SIGNIFICANT CHARACTERISTICS OF SOCIAL RESPONSE TO NOISE AND VIBRATION

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1. Introduction

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Many social surveys, represented by questionnaire surveys, have been conducted to determine the criteria for protecting the human environment from environmental noise and vibration accompanying traffic, factories and construction.

The specific conditions of the effects on various human activities and physiological phenomena have been individually determined, beginning with annoyance to noise and vibration, and very accurate criteria have already been determined in the laboratory [1,2]. However, the effect of noise and vibration which develop as people go about actual social activities must be investigated by social studies since the characters, which vary greatly among individuals, and the positioning of the effects of noise and vibration in general human activity must be analyzed dynamically from the viewpoint of behavioral science.

Many of the sampling methods and social survey techniques are compilations in the field of social science, and methods with actual results are employed there, but the following points must be borne in mind in conducting social surveys on noise and vibration:

1) A measurement of the relation between individual/social response must be found and a quantitative measurement

*Numbers in the margin indicate pagination in the foreign text

of impact must be made to develop a direct linkage with technical countermeasures.

2) There is a great difference in accuracy of measurement techniques between quantity of impact and individual/social response.

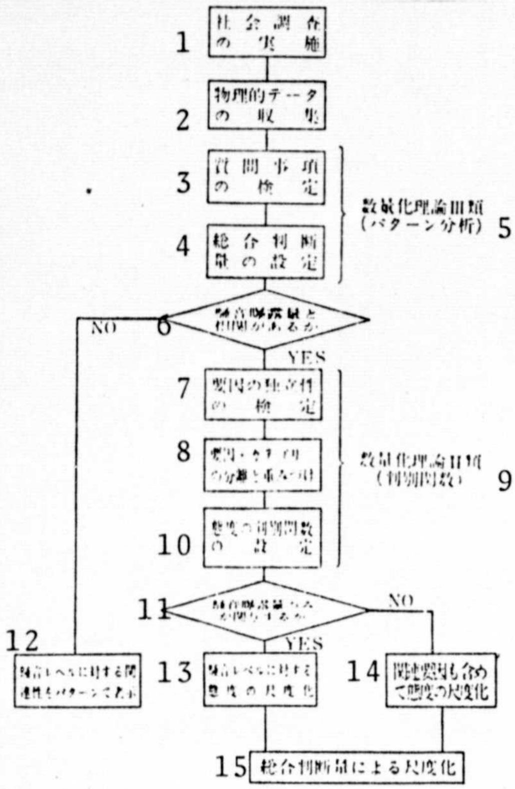

Fig.1 The procedure of designing of social survey, physical measurements and analysis of responses for scaling individual/social attitude to noise and vibration annoyance.

Key -
1. conduct of social survey
2. collection of physical data
3. verification of questioned items
4. establishment of overall judgement
5. quantification theory type III (pattern analysis)
6. correlation with amount of noise exposure

(Key continued on next page)

There has already been a report on consideration of these points [3], and the authors have frequently had opportunities to design and analyze surveys on the effects of noise and vibration.

Thus, in this report, the points believed to be characteristic of behavioral responses to noise and vibration were clarified and extraction of future problem points was attempted.

2. Outline of Survey and Basic Guidelines

Table 1 illustrates the factors participating in design and analysis of surveys by the author among those measurement operations of effects of noise and vibration on the general human environment.

As many researchers of social surveys have indicated, careful attention must be directed to the question of whether or not accurate analysis and extraction of social movement is /149

Key to Fig. 1 continued

7. verification of independent factors
8. separation and weighting of factors and [illegible]
9. quantification theory type II (judgement function)
10. establishment of function for attitude determination
11. is only noise exposure involved?
12. the relation to noise levels is shown by pattern
13. scale of attitudes to noise level
14. scale of attitudes including related factors
15 scale based on comprehensive evaluation

conducted without bias in the design of social surveys.

In addition, since the results of social surveys on noise and vibration are linked with direct technical countermeasures through the course of establishment of criteria, the data among the surveys must be quantitatively interchangeable. Referring to questionnaires by England [4], Sweden [5] and OECD [6] where social surveys were conducted from the same standpoint, an attempt has been made to conduct surveys whose results can be compared based on common points with these survey results.

While there are some differences based on the survey of table 1, the questionnaire used had key questions which are consolidated by the evaluation scale method and the series category method.

Conversely, in treatment of data of the resulting samples, the Likert method has been used primarily until now, but the numerical quantification theory [7,8] was used consistently for the greatest possible numerical quantification of the factors associated with determination of attitudes toward noise and vibration.

Fig. 1 illustrates the procedures from data collection to scale development.

3. Analytical Results of Attitude Responses and Their Characteristics

3.1 Examination of Key Questions

The first step in the development of a scale of attitude responses to noise and vibration, as shown in Figure 1, is to examine the relation between the response to each questioned item and the physical stimulus, using the quantification type III (pattern).

Figure 2 illustrates one example in the case of high speed railway noise. The items in which the responses throughout all collected samples are distributed uniformly are quantitatively arranged into sites near the origin, and items with responses only among specific samples are quantitiatively arranged at points distant from the origin. Accordingly, the regions near the origin exhibit the responses common to the society (region) while the distant points exhibit specific responses.

Conversely, by conducting analysis through similar procedures on the character of each sample, the significance of the axes can be given, In Fig. 2, 1_X corresponds to (noise level).

Figure 2 determines a pattern for the limit of positive response (occasional noise effect) of each item illustrated by the series category method. This figure indicates that each item of /150
the key questions is divided into groups of social activity effect, human activity effect and physiological effect. While the social activity effect group is uniformly projected in relation to noise level, the human activity effect group corresponds to a region of high noise level. In addition, the group of physiological effects does not exhibit a marked correlation within the range of noise levels sampled here. It seems that factors other than noise level contribute to the response.

In this way, selection and integration of the items which

should be scaled can be accomplished by arrangement of all questioned items into a pattern, including the questions on general environment which were inserted to eliminate bias and the key questions. In the case of noise, the items which should be scaled are determined in the groups of social activity effect and human activity effect, but results of various attitude analyses are common to both.

As the next step, the partial correlation coefficient of the factors to external criteria were determined using the response to each questioned item as an external criterion (objective variable) by the quantification type II theory. This is shown in table 2.

Examination of the partial correlation coefficient to each questioned item of [noise level], which is a physical factor noted, reveals a great correlation between the comprehensive judgement and the group of effect on social activities such as telephoning -- listening to broadcasts -- conversing. In addition, there was a great correlation to [surprise] and [vibration] as well. This corresponds to the pattern of Fig. 2.

Accordingly, in developing a scale of attitude response to noise, a comparatively accurate scale develops regarding the group of effect on social activity and the comprehensive judgement to the annoyance of noise, but one must recognize that little else can be expected.

In addition, since the effect of vibration has a strong correlation with [annoyance of noise] discussed below, an examination must be conducted to determine whether the attitude response corresponds to a direct physical factor or whether it is a secondary response.

The above results involve the case of high speed railway noise, but similar tendencies are evident in other social surveys as well.

3.2 Discrimination Function of Attitude Response and Scale Development

Just as the discrimination function of the attitude responses was found, quantifying the relation between each factor and the response to the various key questions in the questionnaire by the type II quantification method, detailed analysis is conducted of the participation of the categories which constitute each factor.

A typical example is the case of the Tokyo International Airport, in which the analytical accuracy was comparatively high in the social surveys conducted thus far (correlation ratio η^2 = 0.376).

Figure 3 takes the external criterion as a comprehensive judgement of the annoyance of noise. The normalized scores given in categories of each factor are set so that greater absolute values in the negative direction are gradings of [annoyance]. An examination of the participation of each factor in relation to the annoyance of noise, which is an external criterion, in terms of the partial correlation coefficient, reveals that the noise exposure level (WECPNL) is greatest at 0.605, followed by the structure of the dwelling at 0.123. Other factors are well below 0.1. Accordingly, the verified result in this case is that there is no great effect on the determination of the attitude to noise annoyance.

Conversely, Fig. 4 applies changes of the judgement probability of attitude determination to normalized scores to a /151

normalized distribution in which the normalized score is a variable. This serves as the discrimination function of the comprehensive judgement to the annoyance of noise.

Figure 5 extracts the relation between the normalized score and the noise exposure level, which is a noted physical factor, from the analytical results of Fig. 3. The judgement probability[1] of the annoyance of noise in relation to noise exposure levels could be determined as shown in Fig. 6 if the normalized scores from Figs. 4 and 5 were eliminated.

In the development of a scale of noise annoyance from these results, a mini-max concept must be introduced in light of the psychological measurement method employed. For example, in establishing the criterion of [extreme annoyance] in Fig. 4, the intersection point of the probability distribution of [extreme annoyance] with the symmetrical distribution concerning the 50% judgement probability of the probability distribution of [somewhat annoying] could be determined as the saddle point.

However, when scaling based on analytical results of social surveys on noise must consider actual countermeasures and expense, the arrangement in the form shown in Fig. 6 would be desirable even in terms of the significance of the basic data.

3.3 Projection of Factors on Physical Quantities and Trade-off

The quantification type II method used in scaling and analysis in this report is quantification by primary coupling model of the

[1]The complaint rate was expressed in the analytical results of past social surveys on noise, but in this report, the judgement probability was taken from the standpoint that the measurement capability was given as the probability of the determination of individual/social attitudes to certain independent factors.

relation between the external criteria given in classification and the factors of qualitative characteristics (given in nominal scaling and in sequential scaling) as is well known.

Accordingly, a trade off is possible in fixing the external criteria by suitable combinations of categories among the factors for attainment of that state. For example, in Fig. 4, the normalized score which can give a 50% judgement probability of [extreme annoyance] is 14.0, but numerous selections of primary couplings of the normalized scores of categories among the factors which are suitable for these conditions could be made from Fig. 3. If the category of one of those factors were altered, the categories of other factors for correction of normalized scores of those categories could be set, and the state of the external criteria could be retained in the original state.

The ability to conduct this sort of trade off signifies that /152 a microscopic examination corresponding to the diversity of society is also being conducted in formulation of actual countermeasures to noise. This is superior to the data treatment method of exhibiting the correlation coefficient in which neither pure totalization, given in parametric form, nor concrete arithmetic properties are detected.

Conversely, when the factor of physical quantity is included, especially when that physical quantity has a sufficiently large correlation coefficient in relation to external criteria, this primary coupling model is used, and the categories among each factor can be projected into physical quantities. Specifically, as shown in Fig. 5, the categories among other factors can be expressed in physical quantities through normalized scores given in the physical factors.

Table 3 illustrates the changes in attitude response based

on differences in dwelling construction, using as an example the trade off conducted with the projected changes of the qualitative factors mentioned above into physical quantites.

Table 3 determines the outdoor noise exposure level at which the same attitude responses develop corresponding to dwelling construction under conditions at which the sum of the normalized scores given in the categories of each factor in Fig. 3 would be 0.0 (the attitude response would be a judgement probability of 15% [extremely annoying] and 72% [somewhat annoying]).

In this procedure, the sum of the normalized scores of categories of factors beyond dwelling structure is 0.0. The normalized score given in the case of wooden dwellings is -0.89. Accordingly, a normalized score of compensation to reach a sum of 0.0 must be 0.89. The corresponding noise exposure level determined from Fig. 5 is found to be 77.0 WECPNL. Specifically, this signifies that in the case of wooden dwellings, the permissible outdoor noise exposure level would be 77.0 WECPNL under fixed external criteria at which the sum of the normalized score would be 0.0 (as discussed previously, since the factors other than dwelling constuction and noise exposure level in Fig. 3 are not significant, these are all taken as 0.0).

This was determined with regard to other dwelling structures also, but the differences among them can be seen as psychological effective noise insulation levels which carried the noise annoyance. An examination of table 3 reveals that this difference is no more than 3.5 dB if we assume as the criterion wooden structures throughout all regions surveyed socially. The actual noise insulation level determined in this way is significant in terms of the manner in which the dwelling is used in everyday life. For example, there are dynamic diversities in the state of window

opening, etc. The difference in noise insulation level physically measured until now has been at least 10 dB between wooden and steel skeleton pre-fabricated dwellings. Thus, this lower difference is quite significant.

3.4 Difference in Attitude Response due to Survey Subject

The response to noise annoyance changes with the noise source and with the characteristics of the region. To examine that point, a comparison was made of the comprehensive judgements of noise annoyance from high speed railroads, airports and bases. The results are shown in Fig. 7. The daily frequency of noise exposure to high speed railroads was 200, which is comparable to aircraft. This comparison is on the abscissa.

This illustrates that the difference in exposure levels to noise which gives a 50% judgement probability is 1 to 2 dB at best, while the variation in judgement is a standard deviation of 4 to 6.5 dB. Thus, there does not seem to be a significant difference in attitude response based on survey subjects so long as the survey is restricted to traffic noise, but more studies are necessary to clarify this point.

3.5 Characteristics of Response in Groups of Social Activity Effect

The group affected by noise in social activities such as /153
telephoning, conversing and listening to broadcasts is great, as discussed previously. To examine this point in detail, the case of high speed railways was selected. This is shown in Fig. 8.

The major characteristic seen in this figure is that the disturbance to telephoning and conversing is equal, and, as shown

in table 2(b), while the variation in judgement has a standard deviation of 8 to 9 dB, the variation in the case of listening to broadcasts was 18 dB. There was also considerable disturbance to broadcast reception even at low noise levels. However, when a certain noise level (here 80 dB (A)) was exceeded, the disturbance became less than that to telephoning and conversing.

This tendency also appears in other survey results [9.10]. The reason can be qualitatively explained based on the existance of visual information, the contents of the information transmitted, the acoustic environment between the receiver and transmitter, and the state of transmission between people, as shown in table 4.

Specifically, since two-way communication is taking place in telephoning and conversing, the speech and reception of acoustic information is controlled through the central nervous system as /154 a sort of automatically controlled system, while in listening to broadcasts, this action is non-existent so long as no special automatic volume control device is attached. In addition, while only the voice is being transmitted in telephoning and conversing, broadcast programs can be varied.

When all of these factors are considered, the disturbance to telephoning and conversing would be virtually equal, while the effect of even low noise levels would be great in listening to broadcasts, and the variation in judgement would be expected to be great along with the diversity in the attitude of listening to broadcasts.

Since the effect of noise on the group of effect in social activities is the basis for determination of the attitude to noise annoyance, the characteristics of the transmission system given in table 4 must be considered and an examination quantifying that is necessary. Naturally, the probability theory of the relation between

intermittent noise exposure and the information lost as a result would have to be considered. An entropy model would seem to be an effective measure for this.

3.5 Differences in Attitude Response to Noise and Vibration

Physical factors such as noise exposure levels have the greatest contribution (partial correlation coefficient) in attitude responses to noise in most cases.

In contrast, analysis by similar means of the attitude response to vibration reveals the physical factor [vibration level] to be the third factor (0.213) after [noise annoyance] (0.424) and [existence of vibration] (0.326) in the case of factory vibration, as shown in Fig. 9.

Figure 10 illustrates the normalized scores of various categories for those factors which have great partial correlation. The attitude response involving vibration sensitivity does not correspond to a physical factor, but it is greatly determined by the memory of a sensitivity to vibration and the subjective response to existing noise.

In regard to noise especially, the phenomenon of [accustomed], which signifies the number of years of dwelling, often indicates a very small partial correlation, but in vibration, the [memory] of vibration in living contributes greatly thereafter to the attitude response.

In addition, since the attitude response to vibration is not always linked with physical factors, when establishing the vibration item which will be a key question in a social survey of noise, one must remember that the response cannot be used as is,

even if it occurs frequently, because of the cause -- effect relation in the physical realm of incidence of noise→occurence of vibration→attitude response to vibration.

Figure 11 determines the judgement probabilities of vibration sensitivity to high speed railways, road traffic and factories. Since the partial correlation is low to the attitude response of vibration levels, which are physical factors, the accuracy of the judgement probability concerning vibration levels would be inferior to that in the case of noise.

3.6 Threshold Values of Background Noise and Vibration Concerning Attitude Response

As seen in Figs. 7 and 11, when the physical levels are low, differentiation is possible into [1] Case of judgement probability approaching a constant level and [2] Case of rapid interception.

This relation is shown in Fig. 12. The original attitude response has a normal distribution to physical stimuli and a threshold value. The threshold level and the level of background noise -- vibration are balanced. Thus, distribution curves with two characteristics form.

In the examples used in this report, the background noise from the city and factories, which was high in the survey results in the vicinity of Tokyo International Airport, corresponds to [1]. In high speed railway noise, since surveys were conducted in regions where there was virtually no background noise, these would correspond to [2].

Treatment pertaining to this sort of background noise -- vibration and threshold value must be considered adequately in scaling

the attitude response to physical quantities.

4. Conclusion

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Various characteristics of attitude response have been clarified from numerous social surveys on noise and vibration.

(1) In samples received from questionnaires which have been prepared to eliminate bias, judgement of effects on various types of living activity and of direct effects on people can be classified into the three types of groups of effect on social activity, groups of effect on human activity and groups of physiological effect.

(2) When samples are collected impartially, focusing on the noise source so that the noise levels sufficiently cover the general living environment, the attitude response to physical levels of noise exhibits the greatest correlation in the group affected in social activity, and the major part of [noise annoyance] in the comprehensive judgement is occupied by the group affected in social activity.

(3) The differences based on survey subjects, such as noise source and survey region, are not significant so long as a comprehensive judgement is made of [noise annoyance], but further research is necessary.

(4) Among the effects of noise on individual behavior in human activities, when a model is constructed in terms of a transmission system via human beings for disturbance to telephoning, conversing and listening to broadcasts, which is the group affected in social activity, qualitative explanation is possible. Accordingly, a future examination, which would measure that disturbance, is required.

(5) The attitude response to vibration does not uniformly correspond to physical factors, contrary to the case of noise, and it is masked by [annoyance] to noise which coexists. Accordingly, when scaling the effects of vibration in physical quantities, the discrimination accuracy will be inferior to that in the case of noise.

(6) The attitude response to noise -- vibration approaches a normal didtribution in physical quantities above a constant level when changes of criteria to physical quantities are taken.

In addition, there is a threshold value of physical quantity in the attitude response. The judgement probability distribution curve to physical levels changes with a balance between background noise and background vibration levels.

This report compiles basic data which will serve as the basis for establishment, analysis and scaling of social surveys on noise. Accordingly, basic criterion values concerning the effects of noise and vibration have been excluded.

Since areas requiring microscopic examination exist in the individual cases, a future study is planned.

In any event, measurement of attitude responses to noise and vibration must be determined in a dynamic and quantitative form of the individual/social behavior in general active environments. This report is a step in that direction.

The various social surveys which formed the basis of this report were conducted primarily by the Environment Agency. The authors would like to express their gratitude to the officials

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